Fermilab

Particle Physics Division

Mechanical Department Engineering Note

Number: MD-Eng-244-A Date: Sept 19, 2012

Project: DAMIC

Project Internal Reference: DAMIC Copper Chamber Test Stand

Title: DAMIC Cu Vacuum Chamber and Flanges Stress Calculations

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Reviewer(s):

Key Words:

Abstract/Summary:
The Copper vacuum chamber and top flange in the original document were analyzed for an applied external pressure of 15 psi. In revision A, the analysis for the external pressure is increased to 40 psi.

Applicable Codes:
ASME DIVISION I SECTION VIII,
ASME Section II Part D
FESHM 5032, Review of Cryogenic Systems
FESHM 5033, Vacuum Vessel Safety

Introduction:

DAMIC uses an 8 inch diameter by 30 inch long copper vacuum chamber. The wall of the chamber is 0.125 inches. The top flange has the vacuum feedthru's and supports the weight of the experimental components.

The vacuum chamber volume is 0.82 cubic feet. If the vacuum volume is more than 35 cubic feet, FESHM 5033 requires that the volume to be considered as a vacuum vessel. The chamber volume is less than the requirements for a vessel, however all of the design verification calculations will be performed as if the volume were a FESHM vacuum vessel.

Collapse Pressure:

The drawing for the vacuum chamber assembly is 466660, and the chamber weldment is drawing 466583. The maximum allowable external pressure for the chamber walls and flanges is determined below.

Section VIII Div I- UG-28 Thickness of Shells and Tubes under external pressure:

Pa is the allowable external pressure

$$Pa = 4B/3(D*t)$$

Where:

D = 8.0 inch Diameter
t = 0.125 inch wall thickness
B = is determined from Figure NFC-1 Section II Part D
= A is 0.007 is Determined from Figure G, Section II part D
= L/D = 30/8 = 3.75 and D/t = 8/0.125 = 64
= 2,000

Then:

Pa = 4* 2000 / 3(8/0.125)
Pa = 41 psid

Under no conditions will the external pressure exceed 41 psi

Minimum thickness required for unstayed flat heads:

The bottom flange of the vessel is welded to the shell. The flange thickness is determined using Section VIII, Division 1 UG-34.

Required Flange Thickness with a 0.8 multiplier on allowable stress:
UG-34 case H, Flat Head Cover, flange welded to the shell.

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$$t = d\sqrt{CP / SE}$$

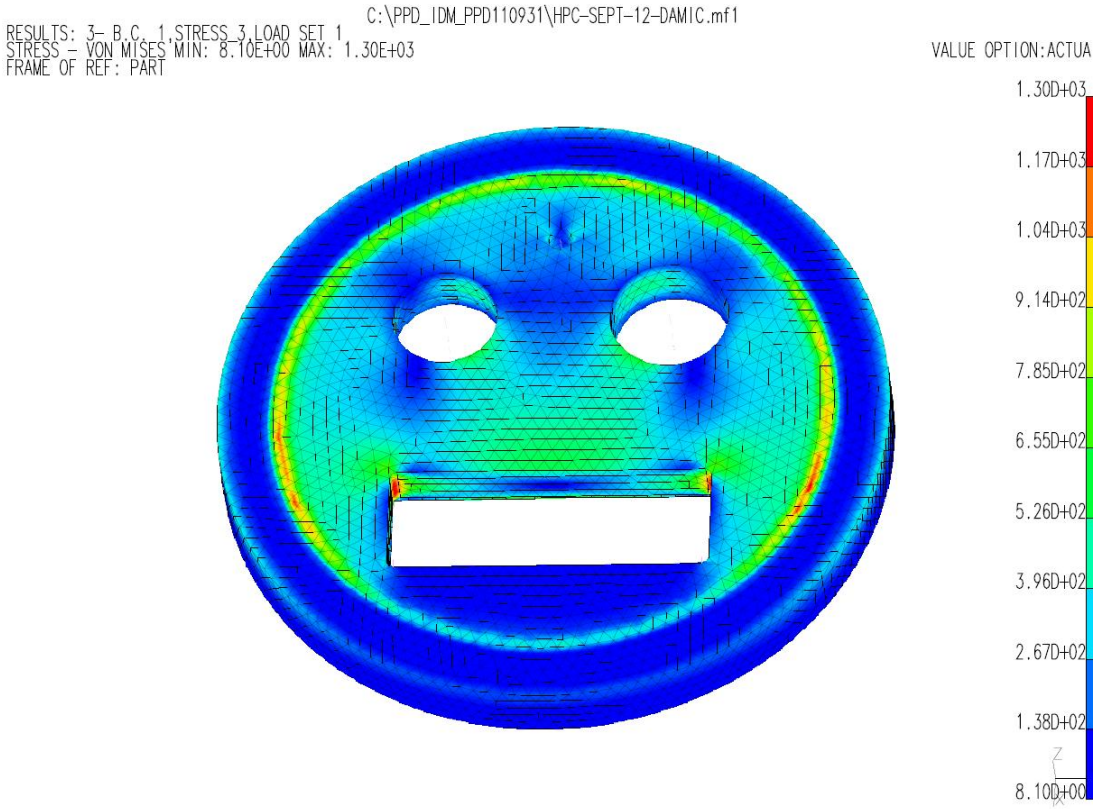
t = minimum head thickness
d = 8 inches, inside flange diameter
C = 0.33 flange attachment factor
S = 0.8 * 5,300 psi NFC-1 fully annealed copper,
Maximum allowable stress in tension
Section II, Part D, Table 1B.
0.8 multiplier for Fermi in house Flange construction.
E = 1, welded joint efficiency
P = 40 psid, maximum external pressure.

t = 0.45 inch, required thickness

The bottom flange thickness is 0.5 inches.

The bottom flange thickness satisfies requirement with a 0.8 multiplier on stress.
At no time will the external pressure exceed 40 psid.

The top flange, drawing 466587, is 1.125 inches thick and has several holes for vacuum feedthrus. An FEA is used to calculate the stresses in the top flange. The flange is supported from the outer edge, and 40 psi loading is applied to the undersurface of the flange.

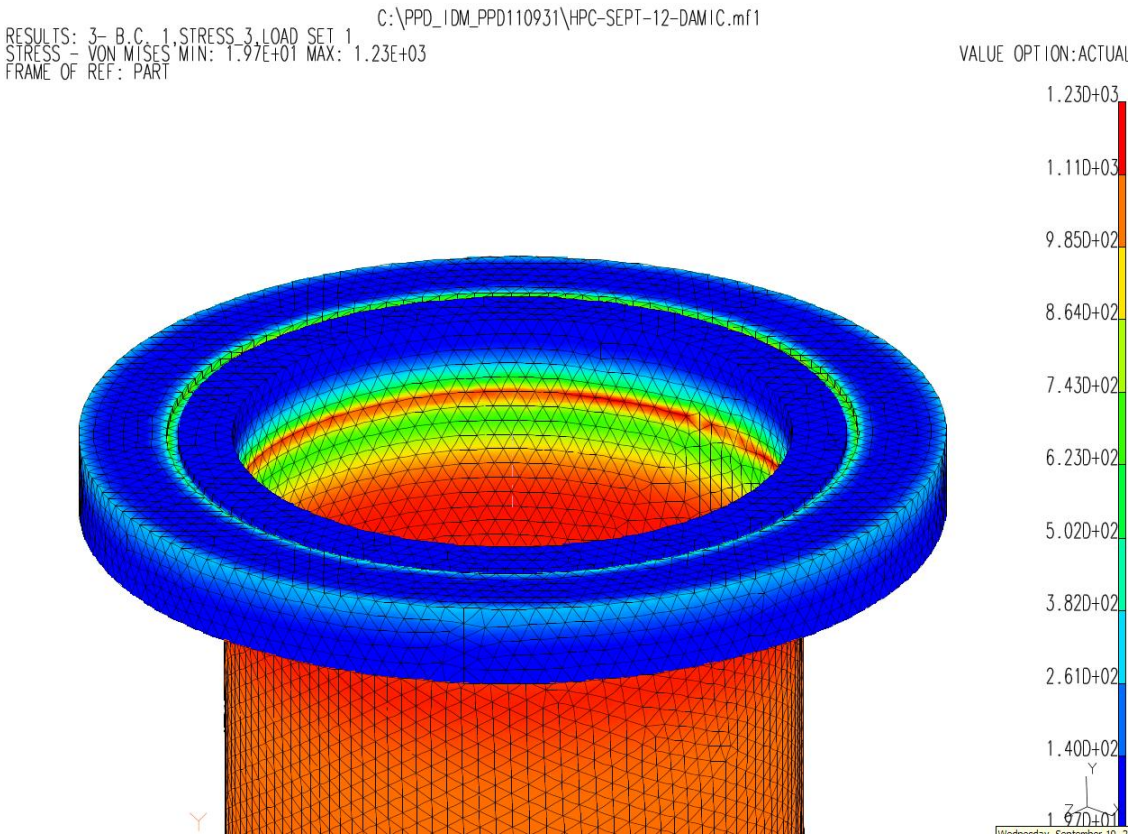


The maximum Von-mises stress is 1,300 psi.

This is significantly lower than maximum allowable stress of 0.8*5,300 = 4,240 psi

Vacuum Chamber Flange

The flange at the top of the vacuum chamber, drawing 466579, is welded to the top of the chamber shell. The vacuum chamber is sealed to the top flange assembly using a flat face flange with an o-ring groove. The o-ring provides the vacuum seal. An FEA is used to calculate the stresses in chamber flange to chamber shell joint. The upper flange is supported on the outer surface from the o-ring groove. Loading is 40 psi vacuum (external pressure) applied to the inner surfaces of the vacuum chamber.



The maximum Von-mises stress is 1,230 psi at the flange to chamber shell joint.

This is significantly lower than maximum allowable stress of 0.8*5,300 = 4,240 psi

Summary

The wall thickness and flange stress on the DAMIC copper vacuum vessel are acceptable under the applied external pressure up to 40 psid.